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MAGNETIC BEHAVIOR OF AMORPHOUS Fe-Ni-Zr ALLOYS AND THEIR RESPONSE TO RADIATION DAMAGE*

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The magnetic properties of two amorphous Fe-Ni-Zr alloys, $Fe_{89.7}Ni_{0.03}Zr_{10}$ and $Fe_{70}Ni_{20}Zr_{10}$, both in the "as cast" and neutron irradiated states were investigated by Mössbauer spectroscopy and dc magnetic susceptibility measurements. The upper magnetic ordering temperatures of $Fe_{89.7}Ni_{0.03}Zr_{10}$ are 232K and 246K for the "as cast" and irradiated samples, respectively. The magnetic ordering temperature for $Fe_{70}Ni_{20}Zr_{10}$ was about 478K for both the "as cast" and irradiated samples. Both compositions yield magnetic hyperfine spectra, which show a considerable relaxation effect that must be explicitly considered in the calculation of the average local Fe moments. When this is done, these values derived from Mössbauer spectra are in good agreement with the dc susceptibility values. The effects of neutron irradiation on the magnetic properties of these alloys are small.

1. INTRODUCTION

As part of a program to determine the effects of radiation on the magnetic properties of amorphous ternary alloys, we irradiated the alloys, $Fe_{89.7}Ni_{0.3}Zr_{10}$ and $Fe_{70}Ni_{20}Zr_{10}$ with 14-MeV neutrons up to fluences in excess of 10^{17} n/cm^2. We report the results of the investigation of these spin-melt generated alloys, irradiated and "as cast", by Mössbauer and dc susceptibility techniques as a function of temperature

2. EXPERIMENTAL METHODS

The spin-melt method produced ribbons ~4×10^{-4} cm thick. This amorphous metal has no grains in the sense of a polycrystalline solid and no detectable voids. Neither crystalline structure nor any second phase is revealed by x-ray diffraction or TEM. Specimens were wrapped as 0.5-cm-long bundles and irradiated at ambient temperature with 14-MeV neutrons generated by the LLNL RTNS-II. The fluence in excess of 10^{17} n/cm^2(3×10^{-4} dpa) received by each specimen was determined from the activation of its self-contained $^{54}Fe(n,p)^{54}Mn$ and the x-ray activity of the 312.5d ^{54}Mn measured by a standard calibrated counting technique. Absorbers were made by gluing several strips of the alloy ribbon to an Al support foil. Mössbauer spectra were obtained from ~4 to 340K, using a ^{57}Co - Pd source at room temperature in moving-source geometry. The spectrometer (model MS-900, Ranger Scientific) was calibrated with iron foil at room temperature. The dc magnetization measurements were made with a commercial SQUID-type magnetometer.

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3. RESULTS AND DISCUSSION

Typical Mössbauer spectra shown in Fig. 1 a-d compare the "as cast" with the irradiated alloys for each composition. There is no devitrification leading to the production of a second phase and, in fact, the spectra are notably unaltered by the irradiation. The magnetic transition temperatures are slightly raised by the irradiation in the Ni(0.3) alloy samples but remain essentially constant for the Ni(20) alloy samples (see Table 1). The asymmetry and broadened outer lines result from the distribution of chemical environments and departure from cubicity associated with the amorphous structure. The broadening of the outer lines could also be due to relaxation effects. If no relaxation effects were operative, the ratio of the separation of lines 3 and 4 to the separation of lines 1 and 6 is given by $D_{34}/D_{16} = (1 - g_1/g_0)/(1 + 3g_1/g_0) = 0.1578$, which is independent of quadrupole coupling. g_0 and g_1 are the respective ground- and excited-state splittings /1/. This value is virtually constant between 4.3 to 340K. If relaxation is appreciable, i.e., the electron-spin flip frequency is comparable to the nuclear Larmor precession frequency, lines 1 and 6 become broadened and their separation also becomes spuriously large /2/. Thus, the observed D_{34}/D_{16} ratio will be less than the above value. We performed least-squares fitting, assuming each spectrum to be a single sextet and from this, calculated the ratios, D_{34}/D_{16}.(Fig. 2). The effect of relaxation is clearly evident in both the Ni(0.3) samples and to a lesser extent in the Ni(20) samples. The values of the average local moments, $\bar{\mu}_{34}$ and $\bar{\mu}_{16}$, in Bohr magnetons (μ_B), as derived from D_{34} and D_{16}, respectively, are shown in Table 1 and compared with corresponding values derived from dc magnetic susceptibility measurements. Values of $\bar{\mu}_{34}$ are consistent with the susceptibility measurements. Values of $\bar{\mu}_{16}$ are significantly higher than the susceptibility measurements which is consistent with the effects of relaxation /2/. Stadnik et al. /3/ found a value of $0.6\mu_B$ to be the local moment on the Ni in the Ni(20) alloy. We adjusted the previously reported average saturation magnetization /4/ by this amount in order to obtain a value for the average Fe moment for this alloy (Table 1).

Table 1

Average Fe magnetic moments of Fe-Ni-Zr alloys (μ_B).

State	$T_O(K)^{a)}$	$\bar{\mu}_{16}{}^{b)}$	$\bar{\mu}_{34}{}^{b)}$	$\bar{\mu}_{Fe}{}^{c)}$
		$Fe_{89.7}Ni_{0.3}Zr_{10}$		
"as cast"	232	2.05 ± 0.0[illegible]	1.83 ± 0.09	1.78 ± 0.04
Irradiated	246	2.09 ± 0.0[illegible]	1.85 ± 0.02	-
		$Fe_{70}Ni_{20}Zr_{10}$		
"as cast"	$479^{c)}$	2.32 ± 0.0[illegible]	2.19 ± 0.10	2.11 ± 0.04
Irradiated	$476^{c)}$	2.33 ± 0.0[illegible]	2.21 ± 0.10	-

a) T_O is the magnetic ordering temperature.
b) Derived from Mössbauer spectra; $\bar{\mu}_{16}$ from separations of lines 1 and 6, $\bar{\mu}_{34}$ from separations of lines 3 and 4.
c) Derived from susceptibility measurements.

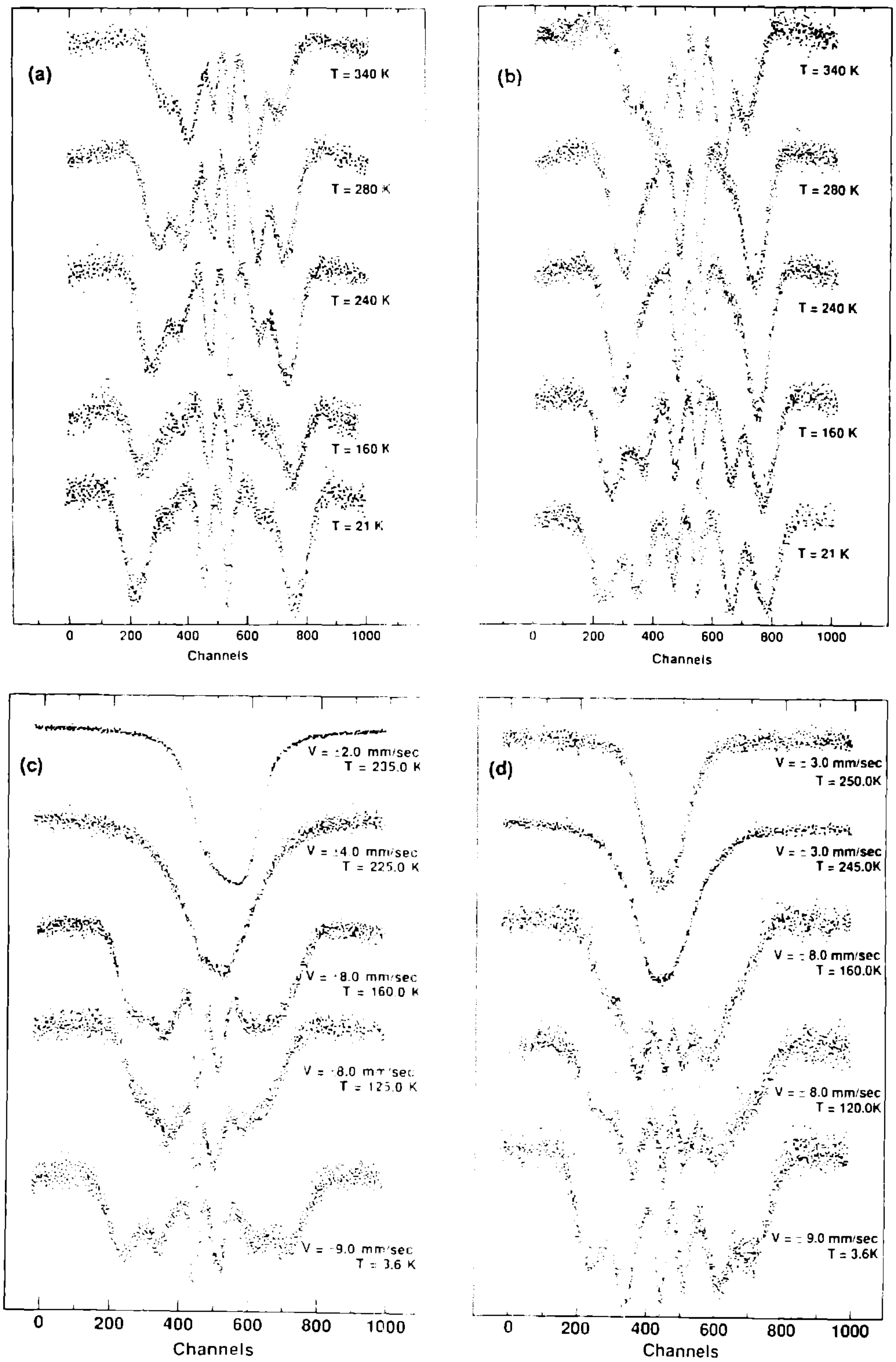

Fig. 1 Mössbauer spectra for (a) $Fe_{70}Ni_{20}Zr_{10}$, "as cast" (V_{max} = ±9.0 mm/s), (b) $Fe_{70}Ni_{20}Zr_{10}$, irradiated (V_{max} = ±9.0 mm/s), (c) $Fe_{89.7}Ni_{0.3}Zr_{10}$, "as cast", and (d) $Fe_{89.7}Ni_{0.3}Zr_{10}$, irradiated.

Perhaps the most significant finding of this investigation is the surprising radiation resistance of these amorphous materials. Also, if allowance is made for relaxation, the average Fe moment as determined from the Mössbauer spectral data agrees with that obtained from susceptibility measurements.

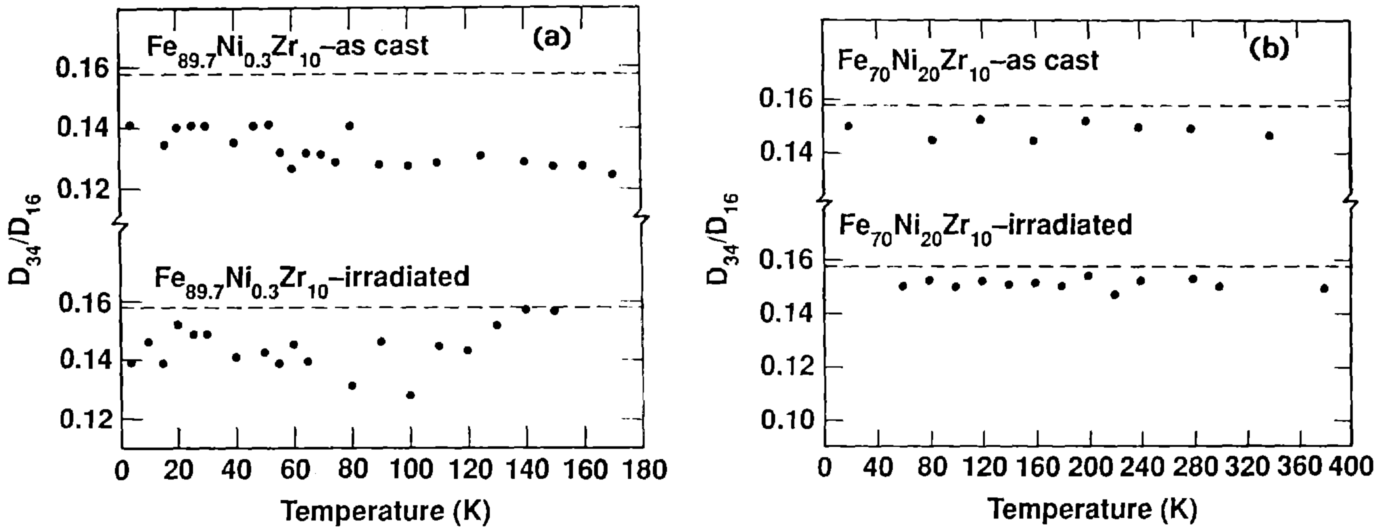

Fig. 2. D_{34}/D_{16} vs temperature for (a) the $Fe_{89.7}Ni_{0.3}Zr_{10}$ alloys and (b) the $Fe_{70}Ni_{20}Zr_{10}$ alloys.

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